

**Auxiliaries and Testing Group**

# THE INTERRELATIONSHIP OF FUNCTIONAL FABRIC PROPERTIES RESULTING FROM THE USE OF SPECIAL TEXTILE FINISHES\*

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1. The application of special textile finishes for the attainment of certain desired functional properties produces both primary and secondary fabric characteristics. For the purpose of this paper, these characteristics may be classified as follows:

(1) **PRIMARY** — Water resistance; fire resistance; mildew resistance; shrinkage control; resistance to chemical or photochemical degradation; crease resistance; and color or shade characteristics.

(2) **SECONDARY** — Breaking strength; tear strength; sewability; seam strength; hand; drape; flexibility at low temperatures; nontackiness; resistance to crocking; color fastness; resistance to perspiration; moisture-vapor permeability; durability of the finish to laundering; maintenance of strength characteristics during laundering; durability to leaching; stability to weathering; stability to aging or long-term storage; wear resistance; nontoxicity; and freedom from objectionable odors.

2. In general the attainment of any one of the primary characteristics through the application of special finishes would be a relatively simple matter were it not for the complicating effects produced on other primary and secondary characteristics. These concomitant effects of finishing treatments become of paramount importance in military fabrics where performance requirements are normally more rigorous than for civilian textiles.

3. The co-operative efforts of research laboratories, technologists and textile mills have gone far in attaining a good balance of those factors attendant on the production of satisfactory finishes. However, the ultimate goal of imparting, through the use of finishing treatments, specific functional characteristics to a base fabric without detracting materially from its inherent good qualities is yet to be reached.

4. A list of special finishing treatments for a variety of fabrics is presented with special attention given to those factors wherein improvement needs to be made.



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## INTRODUCTION

THE word finish may be defined as that which completes or perfects. Hence, textile finishes may be described as those treatments or processes, either physical or chemical, which have as their main objective the completion or perfection of a greige (base) fabric. Finishing processes may be divided into two very broad classes: (a) physical, which includes such operations as drying, singeing, tentering, napping, mechanical preshrinking, shearing, decatizing, calendaring,—in short those operations which are principally mechanical in nature; and (b) chemical, which encompasses the application or deposition of chemical compounds on or within the fibers or fabrics, or the accomplishment of chemical reactions with the fiber itself. This discussion will be limited to a consideration of the latter (chemical) and will then include only a restricted segment of this field as it relates specifically to the functional properties of a few representative types of fabrics.

The use of finishes to impart new or improved characteristics to fabric dates back to antiquity. Dyeing with vegetable,

animal, or mineral coloring matter was among the earliest of textile finishes. It has been reported that starch has been used as far back as 800 BC. According to Marsh (1a) "the earliest known methods of rendering textile fabrics impervious to water seem to have originated in primitive treatments with vegetable exudations, of which rubber latex is perhaps the most famous. . . . The oldest methods of European origin were based on linseed oil and date from the fourteenth century, but by the beginning of the nineteenth century treatments with aluminum soap had been discovered in England." Marsh (1b) further states that "The protection of inflammable material against fire dates back to 400 BC, but the earliest attempts to fireproof textile fabrics are of more recent date; about 1640, attention was drawn to the use of clay and plaster of Paris on canvas used in theaters. Alum was suggested in 1740 and ammonium phosphate in 1786."

The extensive commercial use of special finishing agents, however, to impart new and improved functional characteristics to fabrics without materially detracting from the base fabric's inherently desirable properties is of much more recent origin, having taken place essentially within the last 25 or 30 years. Durable water repellents, mildew inhibitors, fire retardants, shrinkage-resistant treatments for woollens, crease- or muss-resistant agents, mothicides, improved dyes and dyeing techniques, new softening agents, and antistatic compounds have come to the fore during this period. There are literally hundreds of finishing agents on the market today in addition to the thousands of ideas incorporated in the patent literature. One need turn only to the Section on Textile Chemical Specialties in the 1950 *Technical Manual and Year Book* of the American Association of Textile Chemists and Colorists to find an imposing compilation of these products. The

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list available to the textile finisher increases daily.

## DISCUSSION

**PRIMARY AND SECONDARY FABRIC CHARACTERISTICS**—The first requisite in the development of a special finish is that the compound or treatment imparts to the fabric the particular characteristic desired. A shrink-resistant treatment for wool must first impart shrinkage control to the treated fiber or fabric. This requirement having been met, other concomitant effects can be given consideration. These side effects more often than not so detract from the inherently desirable qualities of the fabric that the value of the primary objective (finish) is nullified. It is common experience that, when the ultimate in a particular textile property is achieved, other desirable characteristics suffer. For example, the best over-all results for shrink-resistant wool fabrics are not necessarily those in which the greatest degree of fabric stabilization has been attained. The merits of a fabric are dependent on the integration of many factors. In the case of wool the highest degree of shrinkage control, or even a satisfactory degree, may seriously affect the hand, drape, color (shade), alkali solubility, wear resistance and sewing quality or seam strength of the finished product.

It is possible to arrive at a better appreciation of the problems besetting the research worker, the producer of textile chemical specialties, and the textile finisher by listing the qualities frequently required or desired in a finished fabric, and by considering the interrelationship of one to another. First of all, in preparing such a list one is amazed at the multitude of fabric characteristics encountered. It also brings out a number of critical factors often overlooked. In Table I are listed a number of typical figures along with the required or desired characteristics. The figures in the column below the fabric and opposite a specific characteristic indicate the relative importance of the property. An arbitrary scale has been chosen in which the number one (1) is indicative of primary or major importance, two (2) secondary, and three (3) denotes that the property is of still lesser significance. A zero indicates inapplicability.

The application of special textile finishes for the attainment of certain desired functional properties may produce both primary and secondary fabric characteristics. For this paper, which deals principally with military fabrics, these characteristics have been classified as follows:

(1) **PRIMARY** — Water repellency; fire resistance; mildew resistance; shrink-

age control; crease resistance; moth resistance; and color or shade characteristics.

(2) **SECONDARY** — Low add-on weight; breaking strength, tear strength, sewability; seam strength; resistance to yarn slippage; wear or abrasion resistance; handle; drape; moisture-vapor permeability; flexibility at low temperature; nontackiness; crock resistance; colorfastness to sunlight, laundering, and perspiration; stability to photochemical degradation; durability to laundering or dry cleaning; maintenance of strength after repeated launderings; durability to leaching; freedom from objectionable odor; nontoxicity; compatibility of finish with metallic findings; compatibility with other finishes; and stability to accelerated aging or long-term storage.

To this list of seven primary and twenty-five secondary characteristics others might be added. Secondary properties may

become primary factors according to the particular objective for which the finish is applied. Not all characteristics are operative for any one fabric, the number being determined by the intended use of the end item.

The relative value of any factor may change in conformity with the end use. The ratings as presented in the table are not necessarily the values that are required specificationwise but represent the desired ideal. Quite frequently it is necessary to accept a working balance of the many factors involved.

## INTER-RELATIONSHIP OF PRIMARY AND SECONDARY FACTORS

—An examination of Table I brings out a number of significant points. For the representative types of fabrics listed, low add-on weight, breaking strength, tear strength, sewability, seam strength, moisture-vapor permeability, compatibil-

TABLE I  
FINISHING OBJECTIVES AND FABRIC CHARACTERISTICS

	CLOTHING FABRICS						TENTAGE FABRICS		
	Cloth, Cotton, Sateen, 9.0-oz OD 7 (Wind-Resistant, Water-Repellent)	Cloth, Cotton, Herringbone Twill, 8.5-oz OD 7 (Fire-Resistant, Water-Repellent)	Cloth, Wool Serge, 18-oz OD 33 (Moth-Resistant)	Cloth, Wool Flannel, 10½-oz Shrink-Resistant, OD 33	Sweaters, High Neck, Shrink-Resistant Treated	Undershirts, Winter M-50 Drawers, Winter M-50, OD 30A	Cloth, Cotton, Wind-Resistant Twill, 5-oz OD 7	Cloth, Cotton Duck 12.29-oz, FWW MR, OD 7	Cloth, Cotton, Sheeting 4-oz (Tent Liner)
Relative Importance of Finished Fabric Characteristics*									
<b>PRIMARY</b>									
1. Water-Repellent	1	1	2	0	0	0	1	1	1
2. Fire-Resistant	0	1	0	0	0	0	1	1	1
3. Mildew-Resistant	0	0	0	0	0	0	1	1	1
4. Shrink-Resistant	1	1	2	1	1	1	1	2	1
5. Crease-Resistant	2	3	1	1	0	0	0	0	0
6. Moth-Resistant	0	0	1	1	1	1	0	0	0
7. Color (Shade)	1	1	1	1	2	3	2	2	3
<b>SECONDARY</b>									
(1) Low Add-on Weight	1	1	1	1	1	1	1	1	1
(2) Breaking Strength	1	1	1	1	1	1	1	1	1
(3) Tear Strength	1	1	1	1	0	0	1	1	1
(4) Sewability	1	1	1	1	1	1	1	1	1
(5) Seam Strength	1	1	1	1	1	1	1	1	1
(6) Resistance to Yarn Slippage	1	1	1	1	0	0	1	1	1
(7) Wear or Abrasion Resistance	1	1	1	1	2	2	2	2	2
(8) Hand	2	2	1	1	1	1	0	0	0
(9) Drape	1	2	1	1	2	3	0	0	0
(10) Moisture-Vapor Permeability	1	1	1	1	1	1	1	1	1
(11) Flexibility at Low Temperature	1	1	1	1	1	1	1	1	1
(12) Nontackiness	1	1	1	1	1	1	1	1	1
(13) Crock-Resistance	1	1	1	1	1	1	1	1	1
Colorfastness To:									
(14) Sunlight	1	1	1	1	2	3	1	1	1
(15) Laundering	1	1	1	1	1	1	0	0	0
(16) Perspiration	1	1	1	1	1	1	0	0	0
(17) Stability to Photochemical Degradation	1	1	1	2	2	3	1	1	1
(18) Durability of finish to Laundering or Dry Cleaning	1	1	1	1	1	1	0	0	2
(19) Durability to Leaching	1	1	3	0	0	0	1	1	2
(20) Fabric strength after repeated Launderings	1	1	1	1	1	1	0	0	2
(21) Freedom from Objectionable Odor	1	1	1	1	1	1	2	2	2
(22) Nontoxicity	1	1	1	1	1	1	2	2	2
(23) Compatibility of Finish with Metallic Findings	1	1	1	1	0	0	1	1	1
(24) Compatibility with Other Finishes	1	1	1	1	1	1	1	1	1
(25) Stability to Accelerated Aging or Long-Term Storage	1	1	1	1	1	1	1	1	1

\* 1 indicates primary importance; 2 secondary; 3 slight; and 0 not applicable.

ity with other finishes, and stability to accelerated aging or long-term storage are always of major importance.

The need for low add-on weight or attainment of minimum total weight, especially from a military standpoint, is self-evident. In general the same thing applies commercially, except in those instances where the primary objective is to impart to a very lightweight fabric the properties of a heavier fabric through the use of additives.

Breaking strength has, for years, been used as a criterion for measuring the effect of finishing treatments. Although a useful tool, it is now generally agreed among textile people that too much emphasis has been placed on this factor, while other characteristics have been overlooked. Greater attention needs to be given to tear strength, sewing characteristics, and the maintenance of fabric strength after repeated launderings, accelerated aging or outdoor exposure. The Quartermaster Research and Development Laboratories have found repeated launderings, where applicable, to be an excellent means of indicating potential post-treatment deterioration. This test has also been found to be useful in predicting deterioration in fire-resistant fabrics, which may occur when the fabric is subjected to cyclic leaching (or wetting) and drying in actual use.

Not infrequently the application of an additive to a given fabric results in an increase in breaking strength, although tear strength, sewing quality, and seam strength usually suffer. A decrease in

breaking strength due to chemical or photochemical degradation of the fabric is normally accompanied by a decrease in tear strength. However, lowered breaking strength resulting from the use of a limited amount of softener-lubricant may be attended by an improvement in both tear strength and sewability, while yarn and/or fiber slippage tends to increase. These points are illustrated in Table II. Work at the Quartermaster Research and Development Laboratories indicates that there is a rather close relationship between tear strength, as affected by treatment, and sewability. Thus a decrease in the tear strength of a fabric after treatment has been found to be indicative of a deterioration in sewing quality.

Further evidence of the interrelationship of functional fabric properties may be found in treated wool fabrics. In the case of shrink-resistant-wool items, hand, drape, and color, all critical factors, may be affected. An unexpected difficulty has been experienced by the Quartermaster Research and Development Laboratories with seam slippage in the laundering of shrink-resistant tropical-worsted fabrics. One explanation advanced for this phenomenon is that the shrink-resistant properties of this lightweight loosely-woven cloth prevent the raw edges from matting or felting during laundering. Consequently there is a tendency for the shrink-resistant cloth to pull apart at the seams. The application of mothicides, especially from aqueous emulsion, has been found to reduce the natural water repellency of wool and to increase its wicking or water-

absorption characteristics. It now appears that this deleterious effect may be overcome by combining the mothicide with a wax-type nondurable water-repellent emulsion.

While it is true that the application of special finishes to obtain specific functional characteristics is often attended by undesirable effects, it is also true that the accomplishment of certain desirable characteristics may be accompanied by the enhancement of other properties. A case in point is that of a fire-resistant fabric of which tear strength and sewability is markedly improved by application of a durable-type water repellent.

Many examples encompassing the entire list of functional characteristics in Table I might be cited of the concomitant effects of special finishing treatments. It is not the purpose of this paper to enumerate in great detail the interrelationship of functional fabric properties resulting from the use of special textile finishes. However, it is desired to call attention to the long list of characteristics that must be kept in mind in the development and application of special textile finishes. This is particularly true in the case of military fabrics where requirements are usually more rigorous than for civilian goods.

It is further suggested that in evaluating textile finishes more consideration be given tear strength and sewability along with other applicable factors. In this connection it is sincerely hoped that Table I or some comparable compilation of fabric characteristics will find use as a guide or check list to those who are interested in the development and application of textile finishes.

TABLE II

THE EFFECT OF SOME SPECIAL FINISHING TREATMENTS ON BREAKING STRENGTH, TEAR STRENGTH, AND SEWABILITY

Fabric.	Treatment	Breaking Strength lbs		Tear Strength (Elmendorf) Scale Readings	Sewability Seam Efficiency* Percent
		Warp	Filling		
1. Cloth, Cotton, Broadcloth 3.2-oz, Khaki #1	Untreated	78	18	12.4	48.0
2. Cloth, Cotton, Broadcloth 3.2-oz, Khaki #1	Finish A	70	20	19.0	89.0
3. Cloth, Cotton, Broadcloth 3.2-oz, Khaki #1	Finish B	71	20	19.6	91.0
4. Cloth, Cotton, Uniform Twill, 8.2-oz, Khaki #1	Scoured, mercerized and dyed	..	127	50.9	49.5
5. Cloth, Cotton, Uniform Twill, 8.2-oz, Khaki #1	The same as 4, followed by treatment with a softening agent, framed and preshrunk	..	121	57.3	81.0
6. Cloth, Cotton, Broadcloth	Untreated	92	34	34.4	89.0
7. Cloth, Cotton, Broadcloth	Crease Resistant Treated	62	22	17.2	67.0

$$* \text{Seam Efficiency} = \frac{\text{Strength of Seam}}{\text{Strength of Fabric}} \times 100$$

## CONCLUSION

**IMPROVEMENT IN TEXTILE FINISHES**—Much has been accomplished in the development of finishes for imparting to fibers or fabrics water repellency, fire resistance, mildew resistance, crease resistance, or even specific color characteristics or a combination of two or more of these factors. In general, an answer has been found for most of these functional properties where required. In some cases the treatments produce superior results, in others there is still much to be desired; the ultimate is yet to be reached in any case.

Water-repellent fabrics impermeable to rain and possessing the moisture-vapor permeability of an untreated fabric are still a goal. This problem is probably as much one of fabric construction as it is one of chemical finish.

During the past five years notable advances have been made in the development of durable fire-retardant treatments.

The problems which remain, however, in connection with lower add-on weight, color, flexibility at low temperatures, sewing quality, durability to leaching, outdoor exposure and especially laundering are such as to challenge the ingenuity and capabilities of our best research and technical men.

The perfect mildewcide or fungicidal treatment is yet to be found.

It is felt that shrinkage control in wool items has reached the stage where the major problems are largely ones of plant application and plant know-how. Hand and instability to aging in shrink-resistant wool continues as a factor in certain treatments.

On the basis of tests conducted by the Quartermaster Research and Development Laboratories a completely effective mothicide durable to laundering and dry cleaning is still a desired objective.

In conclusion it may be said that the co-operative efforts of research laboratories, technologists, and textile mills have gone far in attaining a good balance of those factors attendant on the production and application of satisfactory chemical finishes. However, the ultimate goal of imparting, through finishing treatments, specific functional characteristics to a greige (base) fabric without detracting from some of its inherent good qualities is yet to be reached.

## REFERENCE

- (1) Marsh, *An Introduction to Textile Finishing*, Chapman & Hall Ltd, London, England (1947); (1a) p 457, (1b) p 522.

## "Houghton Line" Salutes the AATCC

IN one of a series of descriptive articles giving the history and objectives of prominent trade associations, the AATCC is honored in the April 1951 issue of "The Houghton Line," a publication of E F Houghton & Company, Philadelphia. The article was prepared in close cooperation with the AATCC Publicity Committee headed by George Schuler, *Chairman*.

The "Line" states that "in the special field of textile wet processing, the last 25 years have seen technical advances which have revolutionized procedures, stabilized processes and improved immeasurably the quality and quantity of finished textiles available to meet the growing needs of the trade." They further point out that "assuredly it is not accidental that the period of most significant development coincides with the growth of the American Association of Textile Chemists and Colorists."

The illustrated article covers highlights of the Association's founding and history, brief sketches of its organizational structure and aims, and an outline of its current scope and future. Photographs include those taken at the 1950 Convention as well as recent portraits of current Association officers.

As a conclusion, Houghton "salutes the Association, and wishes its continued healthy growth."

## Research Committee Meeting

(Concluded from Page P342)

Warner, reported that recent government procurements have made the development of the wool shrinkage test an acute problem; the committee is at work on this problem. He stated that Mr Goodavage's hosiery committee has prepared its final report and has concluded that the most representative test is the one in Federal Specification CCC-T-191-A identified as the U S Army Accelerated Test. He also reported that the knit goods group is actively at work.

### FLAMMABILITY—

H E Hager stated that the new method had been accepted at the last meeting, and that there has been general agreement on the work that has been reported including an interpretation of the results of the test. His committee will have in the forthcoming *Year Book* three classes which have been agreed upon:

- (1) Safe fabrics which require more than 7 seconds to burn in the test equipment.
- (2) Intermediate fabrics which burn between 4 and 7 seconds.
- (3) Dangerous fabrics which burn in less than 4 seconds.

He stated that the committee now considers its work finished after five years of active effort, and asked that his committee be given reference status.

Dr Hager referred to the fact that the recent letter ballot on this flammability work brought out the fact that a 50% return is considered normal. Messrs Little and Stiegler amplified on this point and urged that recipients of postcard ballots make definite replies in all instances. If the recipient cannot feel qualified to vote, the card should be returned indicating that fact. It would also be appreciated if reasons would be given when the vote is negative.

Dr Stiegler advised that Atlas Electric Devices is making 12 of the latest Accelerator models and will make them available for sale, probably within two

months. They will be constructed of stainless steel with a container 5½ inches in diameter; the cost probably being in the neighborhood of \$100. Dr Stiegler stated that J R Redmond's committee on Fire Resistance is still active and has suggested that their tentative method be given standard method status. He also stated that a mail ballot will probably be taken on this in the near future.

Mr Little inquired for suggestions from the group on improving these meetings. H G Scull replied that he would recommend a Committee on the Development of Odors from Resin Treated Material, stating that the British are working on this problem. K H Barnard replied that his committee is working on odor development and is seeking an accelerated test. A D Nute stated that the Committee on Resin Evaluation is continuing its study on crease resistance and is now including work on stiffness.

Mr Little thanked the University of North Carolina for its hospitality and entertainment during the two days of the meeting. He again requested that the committee members take their job seriously and give any constructive ideas to him which would help the Executive Committee on Research.

There being no further business the meeting adjourned at 3:08 p.m.

Those present included:

L S Little, *Chairman*

H W Stiegler, *Research Director*

G H Schuler, *Secretary*

W D Appel	E R Kaswell
E H Atwell	P J Kennedy
W L Barker	R G Lawrence
E B Bell	H W Leitch
G R Bellamy	G O Linberg
M J Babey	J Lindsay, Jr
K H Barnard	W F Luther
J R Bonnar	A R Macormac
K S Campbell	J B Neely
W C Carter	A D Nute
H C Chapin	L C Reynolds
H M Chase	R E Rupp
R E Crowell	H A Rutherford
M A Dahlen	H G Scull
C W Dorn	H G Smith
C Z Draves	T R Smith
G J Elkins	R H Souther
A H Gaede	R B Stehle
H E Hager	J A Stevenson
S L Hayes	C A Sylvester
A K Haynes	A F Tesi
W A Holst	P Theel
G H Hotte	A R Thompson
G D Jackson, Jr	F V Traut
R W Jacobs	S G Turnbull, Jr
H Y Jennings	N R Vieira
N A Johnson	S H Williams
J H Jones	P J Wood
H J Jordan	J A Woodruff

H L Young